3.0 PHYSICAL SETTING

3.1 Topography

The Site is located on a west-facing slope just east of a low basin area occupied by the northern tip of Pelican Horn. The northern tip of Pelican Horn is about 2,000 feet southwest of the Site. Parker Horn is 2,500 feet northwest of the Site. The regional topography slopes gently west-northwest towards Parker Horn (Figure 1-1).

Site elevation ranges from approximately 1,100 feet at the southeast corner of the Site to about 1,055 feet along the west property line (Figure 3-1). The slope of ground surface on the Site ranges from 0 to 30 percent. The Site topography is generally flat in the Western Portion of the Site rising toward the eastern third of the property in the area of the existing operations and maintenance shop. There is an existing fill slope up to 10 feet high along Wheeler Road at the south property line.

3.2 Soils

The Site is located within two soil mapping units (USDA, 1984): Ephrata fine sandy loam, 0 to 2 percent slopes across the West Portion of the Site; and, Wiehl fine sandy loam, 15 to 35 percent slopes across the northeastern portion of the Site. Field observations (Sage, 1993) indicated that the soils comprise medium brown to dark brown sandy silt with silty sand. The upper one-foot is commonly blocky due to frost and/or partial cementation (Sage, 1993).

Century West (1992) reported that the Site soils more closely matched the Endicott series, soil inclusions that are not designated as a definable mapping unit. The Endicott series are described as grayish brown silt loams about 7 inches thick overlying 30 inches of brown silt loam. The subsoil is a white silt loam about 25 inches thick. At depths of approximately 60 inches bgs there is a hardpan that is cemented with lime and silica.

3.3 Geology

This section describes the regional geologic setting followed by site-specific geology encountered during subsurface investigations at the Site.

3.3.1 <u>Regional Geology</u>

The Site is located within the central portion of the Columbia Plateau. The geology of the Columbia Plateau comprises basalt flows overlain in places by sedimentary overburden. In Moses Lake, the sedimentary overburden comprises Pliocene sediments of the Ringold Formation overlain by varying thicknesses of late Pleistocene Missoula Flood deposits, which are in turn overlain by younger dune sand deposits.

3.3.2 <u>Site Geology</u>

The Site is about 2,000 feet northeast of the northern tip of Pelican Horn. The geologic map of Washington, southeast quadrant (Schuster et. al, 1997), indicates that the Site is on a narrow strip of Ringold Formation sediments bounded to the east and west by Missoula outburst flood deposits. Due to the proximity of the Site to Pelican Horn, it is likely that recent fine grained lacustrine/wetland type deposits overlie the Ringold and Missoula Flood deposits in this area. Schuster et. al. (1997) describe the Ringold Formation sediments in this area as interbedded fluvial and lacustrine sand, silt and clay beds with local pebble lenses containing indurated calcium carbonate or siliceous layers (also known as caliche). Schuster et. al (1997) describes the Missoula Flood deposits in this area as fluvial gravels with minor silts and clays and subordinate Ringold Formation sediments and caliche.

3.3.3 Groundwater Technology Investigation - 1993

Based on the RI work completed at the Site in 1993 (Groundwater Technology, 1994), the geology over the eastern part of the Site (in the vicinity of the maintenance shop and office building) comprises:

- 0 - 2 feet bgs: silty sand with gravel.
- 2 - 9 to 14 feet bgs: fine grained sand with up to 25% silt and clay with the silt/clay fraction increasing from southeast to northwest.
- 9 to 14 – 18 feet bgs: partially cemented fine sand, silt and clay.
- 18 - 22 feet bgs: silt and clay.

Sage (1993) noted that calcium carbonate cemented sandy silts and silty sands occur approximately one foot above the groundwater surface and extend downward to the bottom of all test pit excavations.

3.3.4 Golder Investigation, 2002

Geologic units encountered during Golder's 2002 geotechnical test pit exploration program are summarized below. The locations of the test pits are shown in Figure 2-2 and the test pit logs are included in Appendix A with the RI field logs.

- **Fill** – Fill was encountered in all the test pits extending to depths of between about 1 and 7 feet bgs (below ground surface). Fill soils generally consist of a varied mixture of loose to dense silt, sand and gravel with variable amounts of cobbles and boulders, and a trace of organics (roots, branches, and wood debris), asphalt, and concrete debris. Golder test pits GA-TP-1, GA-TP-4, GA-TP-5, GA-TP-6, and GA-TP-10 (Figure 2-2) encountered cobbles and boulders (clasts of native rock, asphalt, concrete) and trash (rubber, wood, cardboard, rebar, carpet, and brick debris). Golder test pit GA-TP-9 about 20 feet south of the concrete lined sweeper pit (Figure 2-2) encountered an unmarked drain pipe bedded in washed rock backfill. The upper 0.5 feet of the fill in the roadway areas consisted of a crushed rock. Petroleum odor and staining during excavation of several of the test pits were observed.
- **Wetland Deposit** - The wetland deposit underlies the fill throughout the lower areas west of the existing operations building. This unit was observed in Golder test pits GA-TP-1, GA-TP-2, GA-TP-4 through GA-TP-8, and GA-TP-10 (Figure 2-2) extending to depths of greater than 14 feet bgs. This unit generally consists of very loose to compact, interbedded, massive to laminated silt with some fine to coarse sand and a trace of fine gravel ranging to fine to medium sand, with a trace ranging to some silt, a trace of organics (roots and rootlets) throughout. Moderate to severe caving and flowing soils were observed while excavating in this unit.
- **Fluvial Deposit** - Fluvial deposits were encountered in Golder test pits GA-TP-2, GA-TP-5, GA-TP-6, and GA-TP-8 (Figure 2-2) at depths of between 5 and 9 feet bgs underlying the wetland deposits. In some areas due to caving conditions, the bottom of the test pits did not extend beyond the wetland deposits and it was not determined if

underlying fluvial deposits were present. When encountered the fluvial deposits consisted of compact to dense, fine to coarse gravel and cobble with a little to some sand and a trace of silt ranging to fine to coarse sand with a trace of silt.

- **Ringold Formation** – The Ringold Formation was encountered (3.5 feet bgs) in test pit GA-TP-3 located on the up slope side of the existing soil stock pile adjacent to the north side of Wheeler Road (Figure 2-2). The Ringold Formation as observed in GA-TP-3 consists of very dense, massive, calcified, tuffaceous silt with a little fine sand.

3.3.5 Remedial Investigation, 2003

During the RI field investigation a total of 30 GeoProbe (designated GP-), four hollow stem auger completed and monitoring wells (designated MW-), and two hand auger holes (designated HA-) were drilled, six test pits (designated TP-) were excavated and groundwater samples collected and analyzed from nine Site monitoring wells (new and previously existing) and six GeoProbes. A Golder geologist examined and logged the soil conditions observed in the GeoProbe and hollow stem auger borings, hand auger borings and test pits. Pertinent information including depths, stratigraphy, and soil engineering characteristics were recorded. The stratigraphic contacts indicated on the summary logs represent the approximate boundaries between soil types. The soil samples were classified in accordance with Golder Associates Inc. Technical Procedure for Field Identification of Soil (TP 1.2-6), which was presented in the RI/FS Study Work Plan (Golder, 2003). The detailed boring and test pit logs are included in Appendix A. The locations of the borings and test pits are shown on Figure 3-2. The soil and groundwater conditions were those recorded for the locations and dates indicated and may not necessarily represent those of other times and locations.

Based on the subsurface conditions encountered during the RI in test pits, GeoProbe borings and well borings, the project site is underlain by some or all of the following units: fill, wetland deposits, fluvial deposits and Ringold Formation sediments. The general description of these soils units are the same as the 2002 investigation. Table 3-1 summarizes the subsurface stratigraphy encountered during the RI.

Fill was encountered at ground surface in all test pits and boreholes (Figure 3-3). The thickness of fill encountered ranged from:

- 1.5 to 8 feet below ground surface in the eastern investigation area
- 1.4 to 6.7 feet below ground surface in the central investigation area
- 2.5 to 4 feet below ground surface in the western investigation area

Fill soils generally consist of a varied mixture of loose to dense sand with varying amounts of silt, gravel and occasional cobbles with trace of organics (roots, branches, and wood debris), asphalt, concrete and small chips of paint. The fill soils in TP-01 extended to the bottom of the test pit at 8 feet bgs, significantly deeper than the 2.2 and 3 feet of fill soils encountered in nearby TP-02 and TP-03. This suggests that TP-01 may be located in the area of soils excavated for the previous diesel tank soil removal.

Over the eastern investigation area, the fill soils directly overlie Ringold Formation sediments. The Ringold Formation sediments generally comprise dense, brown and reddish brown sands and silts with very dense calcified layers, often referred to as caliche.

Over the central and western investigation areas, varying thicknesses of wetland deposits and/or fluvial deposits underlie the fill and overlie the Ringold Formation. The wetland deposits comprise gray-brown fine sands and silt with rootlets. The fluvial deposits comprise gray-brown sand and gravel with occasional cobbles.

Soil physical tests were conducted on soil samples collected to characterize the soil properties of the subsurface materials. Soil testing included grain size analysis, moisture content and specific gravity on a total of three samples described as fill, wetland deposits and Ringold Formation units. In addition, porosity and dry density were determined for the Ringold Formation sample. Due to issues with the volume and/or the disturbed nature of the fill and wetland deposit samples, it was determined that laboratory testing for porosity and dry density in these soil units would yield inaccurate results and therefore was not performed. Table 3-2 summarizes the soil properties evaluated from samples collected during the RI. The physical parameter soil data reports are provided in Appendix B.

3.4 Hydrogeology

Based on our understanding of the Site geology, the generalized conceptual hydrogeologic model for the Site comprises:

- A surficial unconfined aquifer in the fill, wetland deposits and fluvial deposits.
- A laterally discontinuous semi-confining unit (aquitard) corresponding to the Ringold sediments.

Previous and current studies indicate that groundwater is relatively shallow at the Site (between 2 and 9 feet bgs).

Century West (1992) and Groundwater Technology (1995) encountered groundwater over the East Portion of the Site at depths ranging from 2 to 6 feet bgs. Sage (1993) encountered groundwater over the East Portion of the Site at depths ranging from 3.5 to 9 feet bgs. In the remedial investigations for this study, Golder encountered groundwater over the eastern investigation area in GeoProbe (GP-01, GP-02 and GP-03) and test pit (TP-01, TP-02 and TP-03) explorations between about 2 and 5 feet bgs and within existing monitoring wells at between 2.2 and 6.9 feet bgs (Table 3-3).

Golder (2002) encountered groundwater over the central investigation between 3 to 8 feet bgs. In the remedial investigations for this study, Golder encountered groundwater over the central investigation area in GeoProbe borings (GP-04 through GP-16) at between 2.7 and 4 feet bgs and in test pit excavations (TP-04, TP-05 and TP-06) between about 4 and 4.5 feet bgs. Groundwater was measured within the new monitoring wells within the central investigation area (MW-15, MW-16, MW-17 and MW-18) between 3.3 and 3.9 feet bgs (Table 3-3).

In the remedial investigations for this study, Golder encountered groundwater over the western investigation area in GeoProbe borings (GP-17 through GP-23) at about 2 feet bgs. It was noted during drilling that groundwater in the borings rose from between 2.7 to 4 feet bgs to about 2 feet bgs in all borings. This suggests that the dense surficial fill material may have a low permeability.

A full round of groundwater level measurements was made by Golder on April 1, 2003 at existing and new monitoring wells. Based on a survey of the well measuring points (top of casing) completed by the City of Moses Lake between April 1 and 2, 2003, the groundwater elevations at the wells are summarized in Table 3-3. Figure 3-4 presents the groundwater elevations in plan for the Site, groundwater table contours and inferred groundwater flow directions. Based on the April 1, 2003 groundwater elevations, the general groundwater flow direction beneath the East and Central Portions of the Site is northwest as depicted in Figure 3-4.

The general groundwater flow direction is towards the northwest and follows the general surface topography. For the eastern investigation area, where groundwater monitoring has been conducted in the past, the horizontal hydraulic gradient based on the April 1, 2003 monitoring event was 0.07 ft/ft between MW-12 and MW-10, 0.05 ft/ft between MW-02 and MW-05, 0.3 ft/ft between MW-04 and MW-06 and 0.08 ft/ft between MW-02 and MW-08. This indicates that the horizontal hydraulic gradient is higher where the ground surface slope is steeper. For the central investigation area where the four new wells are located, the horizontal hydraulic gradient is significantly lower than the eastern area. The horizontal hydraulic gradient based on the April 1, 2003 monitoring event was 0.01 ft/ft between MW-15 and MW-16, MW-15 and MW-17 and between MW-18 and MW-17. Based on groundwater level monitoring completed for previous studies (Groundwater Technology, 1995), seasonal fluctuations of the groundwater elevation over the eastern investigation area are one foot or less, with no distinct time of the year having higher groundwater level for all wells. Based on communication with City personnel, groundwater sometimes reaches ground surface over the central investigation area, in particular at the base of the gravel storage area slope (next to GP-04, GP-09 and MW-15).

Four slug tests completed in 1993 at four separate wells on the East Portion of the Site (Groundwater Technology, 1994) indicate that the hydraulic conductivity of the silt and sand unit between 3 and 14 feet bgs ranges between 5.0×10^{-4} and 1.6×10^{-3} cm/s (1.6×10^{-5} and 5.2×10^{-5} ft/s). Based on the interpretation of the geologic units presented in this study, this is most likely to be representative of the Ringold Formation sediments. Groundwater flow rates over the East Portion of the Site were estimated at 0.5 to 1.5 feet per day in a northwest direction.

Slug tests were completed by Golder for this RI study on April 1, 2003 in MW-15 and MW-17 within the Central Portion of the site. A summary of the test results is included in Table 3-4. Details of the test analyses are included in Appendix B. Using both the rising head and falling head test results, the hydraulic conductivity of the screened geologic units from the water table to about 15 feet bgs in MW15 and MW17 (i.e. fill, overlying wetland / fluvial deposits overlying Ringold Formation sediments) ranges between 6.9×10^{-5} and 2.4×10^{-4} ft/s. Using the results of the rising head slug tests as most representative of the shallow aquifer in surficial geologic materials that include the three geologic units encountered by the wells, the hydraulic conductivity ranges between 2.1×10^{-4} and 2.4×10^{-4} ft/s (or 18.1 to 20.7 ft/day).

Using the equation,

$$V = K / I \qquad \text{(Equation 1)}$$

Where,

V = groundwater velocity (ft/day)

K = hydraulic conductivity (ft/day)

I = calculated hydraulic gradient, based on measured water levels in Site wells (ft/ft)

And, assuming a hydraulic gradient of 0.01 ft/ft (based on the April 1, 2003 groundwater levels in the new wells), the groundwater flow velocity over the Central Portion of the Site is approximately 0.2 feet per day.

3.5 Meteorology

The Site is located in the central Columbia Plateau in the rain shadow of the Cascade Range. The climate of the region is classified as semi-arid, with hot dry summers and abundant sunshine. In the summer, large diurnal temperature variations are common as a result of intense solar radiation and night-time cooling. Winters are cool, with occasional precipitation, overcast skies and fog.

According to historical information from the Western Regional Climate Center for the Moses Lake 3 E climate station from 1943 to 1979, average annual mean temperature is 49.0 degrees Fahrenheit (F) with monthly mean temperatures ranging from 26.1 degrees F in January and 70.4 degrees F in July. Highest daily temperatures (up to 113 degrees F) are experienced in August. Lowest daily temperatures (down to -33 degrees F) are experienced in February.

The mean annual total precipitation is 7.87 inches with a range of 4.17 to 12.07 inches for the period of record. Precipitation is generally highest in winter (on average about 1-inch per month during November, December and January) and lowest during summer (between 0.3 and 0.4 inches in July, August and September). A portion of the precipitation falls as snow between October and March.

3.6 Demographics

The population of Grant County in 2000 was 74,698. This represents a 36.3% growth from 1990. The population of the City of Moses Lake in 1990 and 2000 were 11,235 and 14,953, respectively. Agriculture is the principal economic activity, especially fruit and vegetable production. Tourism is also a significant and rapidly growing part of the local economy, particularly for outdoor recreation.

3.7 Water Supply

Water is supplied to the Site and immediate surrounding area by the City of Moses Lake public pressurized system. An evaluation of groundwater use in the Site vicinity is provided in Section 4.2.

3.8 Ecology

The local ecology is a function of topography, climate, and hydrology. The Columbia Plateau area around Moses Lake is a high desert ecosystem, which is classified as steppe or shrub-steppe. Bunchgrass and sagebrush comprise the majority of the vegetation in this ecosystem. However, in the more immediate area of the maintenance facility there are wetlands with mostly emergent vegetation, and some scrub-shrub and tree vegetation. The wetland areas are a result of the Site's proximity to Moses Lake (approximately 0.4 miles from the Parker Horn branch of the lake, Figure 1-1); the water table is relatively high. In addition, the areas north and south of the Site are lower in elevation relative to the surrounding developed areas, and can receive surface water runoff from those areas.

Species listed under the Endangered Species Act include Pygmy rabbit (*Brachylagus idahoensis*), Bald eagle (*Haliaeetus Leucocephalus*), Bull trout (*Salvelinus confluentus*), and Ute ladies'-tresses (*Spiranthes diluvialis*). The bald eagles are considered a transient visitor to the area surrounding the Site and the adjacent wetland areas are not considered Bull Trout habitat. There are a variety of birds that can be observed in the general vicinity of the Site including but not limited to songbirds, waterfowl, and raptors. Additional details regarding wildlife present in the Site vicinity are provided in Appendix C.